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(71) Applicant
Smiths Industries, plc,
765 Finchley Road,
London NW11
(72) Inventors
Peter Kenneth Grantley
Rush,
Robin John Taunt,
Kenneth Albert Goreham
(74) Agents
Smiths Industries, plc,
J. M. Flint and P. L.
Williamson,
Cricklewood Works,
London,
NW2 6JN

(54) Furnace elements and furnaces

(57) An electric furnace has a furnace element (2) comprising an electrically-insulative ceramic tube (4), for example of alumina, coated along its outer surface with a layer (20) of an electrically-conductive ceramic, such as calcium-doped lanthanum chromite. At its ends (21, 22), the thickness of the conductive coating is increased and a further coating (23, 24) of a conductive metal is deposited thereon via which electrical connection of the conductive ceramic coating is made. The furnace has an electrical supply (3) that applies a voltage along the length of the coating (20) so as to heat the interior of the tube (4). The voltage is controlled to produce a constant temperature.

Fig. 1.

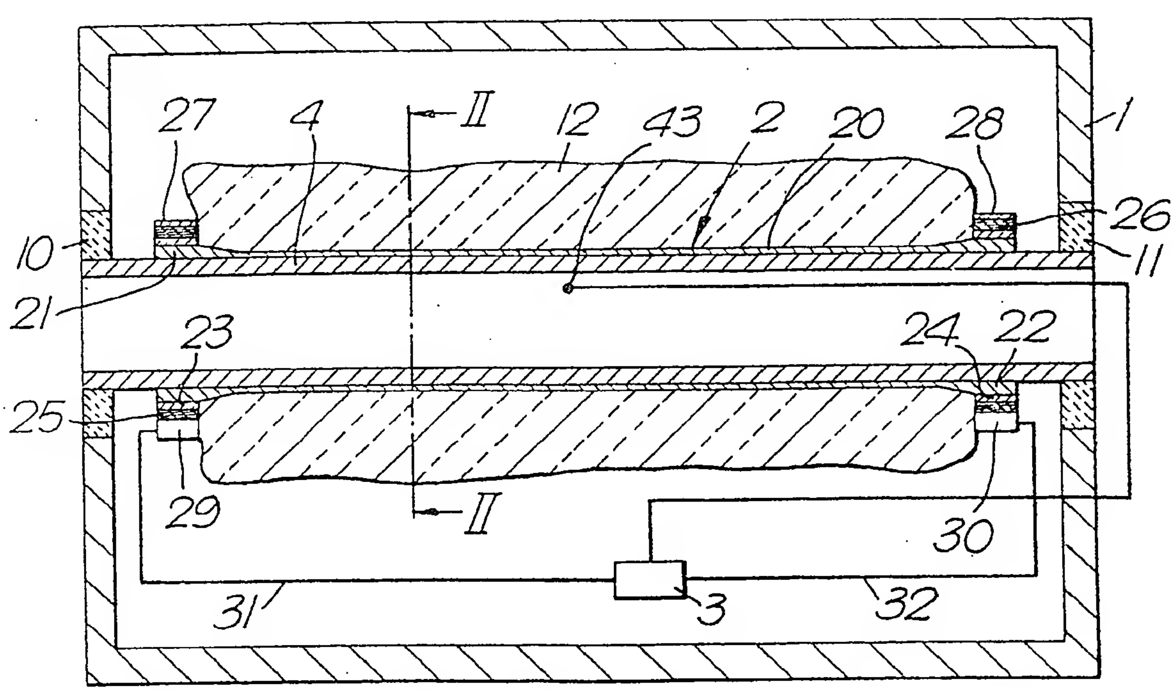

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Fig. 1.

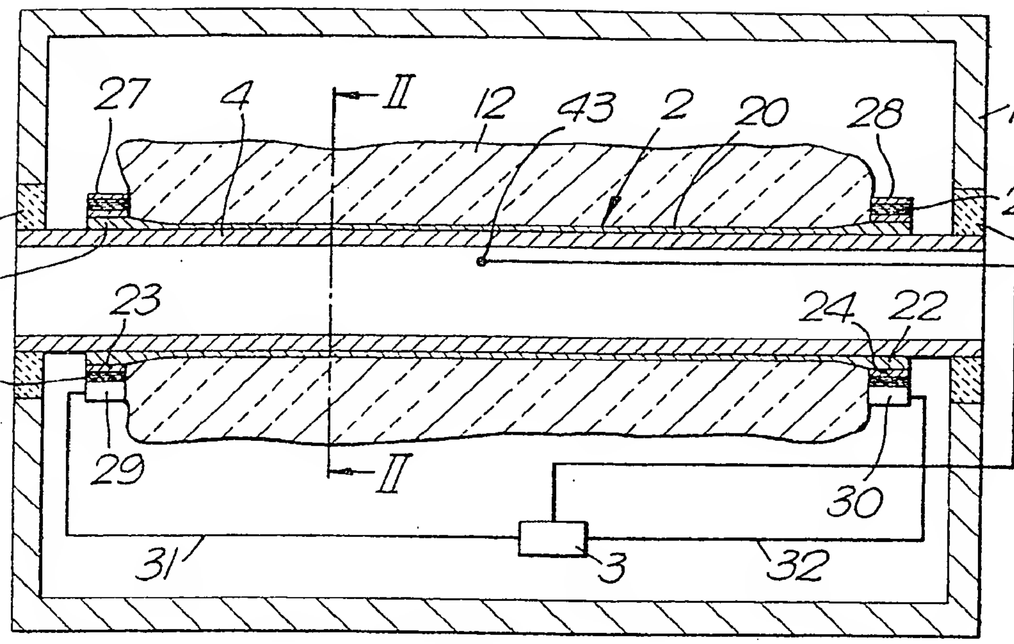
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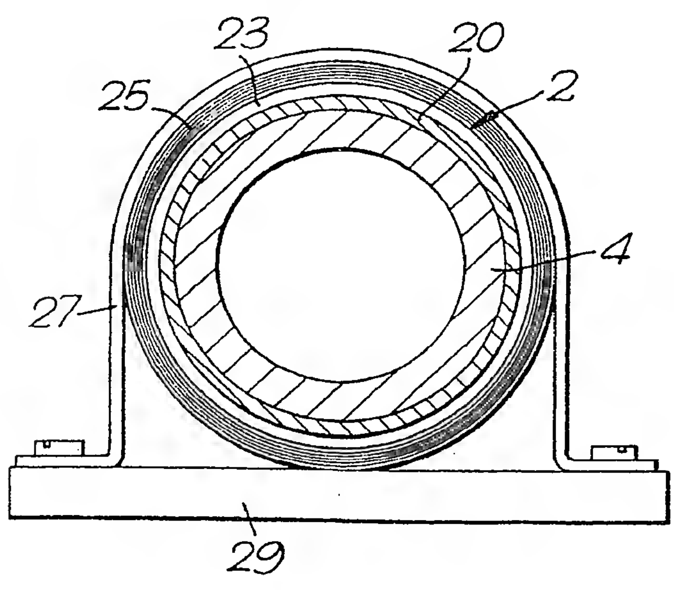
Fig. 2.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SPECIFICATION
Furnace elements and furnaces

This invention relates to furnace elements, furnaces including such furnace elements, and the manufacture of furnace elements.

Furnaces are constructed in many different forms for a large number of different applications. In one form, the furnace has a tube of ceramic or other material into which the object or substance to be heated is placed; heating is produced by metal coils wrapped around the tube or by electrical heating rods, such as of silicon carbide or molybdenum silicide, extending along the outside of the tube close to its surface.

Because of relatively poor thermal transfer between the heating element and the tube, furnaces of this kind are inefficient, producing considerable wasted heat. They are also slow to heat the tube to the required temperature, and can produce an uneven temperature along the length of the tube. The particular heating elements used in this kind of furnace make them relatively expensive to manufacture and operate.

Furnaces are also known in which the heating element is in the form of an electrically-conductive tube (such as, of graphite or zirconia) within which the object to be heated is placed, the tube being heated by passing electrical current along it. These furnaces have been proposed for use in atomic absorption spectroscopy and for melting substances such as metals. Whilst these furnaces have certain advantages they are not suitable for many applications because of the risk that, if the object comes in contact with the wall of the tube it might be damaged by the electric current flowing through the wall of the tube. Also, difficulties arise at high temperatures where, for example, graphite is used as the material from which the tube is made, since the tube must be kept in an inert atmosphere to prevent oxidation.

It is an object of the present invention to provide a furnace element, and a furnace that may be used to overcome the above-mentioned difficulties.

According to one aspect of the present invention there is provided a furnace element comprising a tubular member of an electrically-insulative ceramic material, said tubular element being coated on its outer surface along a part at least of its length with an electrically-conductive ceramic material, such that, by passing current through the conductive ceramic material the interior of the tubular member can be heated.

Because the heating element, that is, the coating is in direct thermal contact with the insulating ceramic tubular member, heat transfer is good and the temperature can be evenly distributed along the length of the furnace.

The electrically-conductive ceramic material may be an oxide, such as lanthanum chromite doped with calcium, the tubular member being of alumina. The coating may be applied around the entire circumference of the tubular member, the end portions of the tubular member being uncoated. The coating may vary in thickness along the length of the furnace element being thicker at the ends of the coating to which electrical contact is made.

According to another aspect of the present invention there is provided a method of manufacture of a furnace element comprising the steps of providing a tubular member of an electrically-insulative ceramic material and forming on the outer surface of said tubular member along a part at least of its length a coating of electrically-conductive ceramic material.

The coating may be applied by plasma spraying and, where said coating is of lanthanum chromite doped with calcium, a thin coating of chromium oxide may be applied to said tubular member prior to said coating of lanthanum chromite.

According to a further aspect of the present invention there is provided a furnace including a furnace element having a tubular member of an electrically-insulative ceramic material, and electrical means for heating said tubular member, the tubular member being coated on its outer surface along a part at least of its length with an electrically-conductive ceramic material, and the electrical means being connected with the coating and arranged to supply current therethrough.

The electrical means may be arranged to control the voltage across the coating in response to change in temperature of the furnace, such as to tend to maintain said temperature substantially constant.

A furnace including a furnace element, and a method of making a furnace element according to the present invention, will now be described, by way of example, with reference to the accompanying drawing, in which:

Figure 1 is a sectional elevation of the furnace along the length of the furnace element; and

Figure 2 is a cross-sectional view of the furnace element along the line II—II to an enlarged scale.

The furnace has an outer housing 1 that supports opposite ends of the furnace element 2 and that includes a control circuit 3 for controlling heating of the element.

The outer housing 1 of the furnace may be of metal, having heat-resistant support members 10 and 11, such as of ceramic material, by which the furnace element 2, is wholly or in part supported. Thermal insulation 12 between the housing 1 and the element 2 reduces heat loss from the element.

The furnace element 2 has a tube 4 of a recrystallised alumina material with an outer diameter of about 3 cm and a length of about 30 cm. The middle 20 cm or so of the tube 4 is coated on its outer surface with a layer 20 of a refractory electrically-conductive oxide, such as, lanthanum chromite doped with calcium by substituting about 15% of the lanthanum with calcium. The ends of the element 2 by which it is

supported are uncoated. Typically, the thickness of the layer 20 (which is shown to an exaggerated scale in the drawing) is about 0.4 mm over the major part of its length, increasing to about 0.6 mm at the ends of the layer, over regions 21 and 22 which are between 2 and 3 cm long.

Electrical contact is made with the layer 20 by applying further coatings 23 and 24 of conductive silver metal, over the end regions 21 and 22 to form respective electrodes. Braided tapes 25 and 26 of stainless steel are wrapped over the silvered regions 21 and 22 and compressed firmly into contact by means of metal straps 27 and 28 which clamp the element 2 to respective metal terminal blocks 29 and 30. Electrical contact of the layer 20 is made with conductors 31 and 32 via respective blocks 29 and 30.

The conductors 31 and 32 connect the furnace element 2 with the control circuit 3. The control circuit 3 may include a proportional controller that is arranged to vary the voltage applied across the element 2. The control circuit 3 receives signals from a thermocouple, or other temperature sensor 43, located inside the furnace element 2 and maintains the desired temperature within the element by varying the voltage applied across the layer 20.

The furnace element 2 opens from the furnace at one or both ends so that articles or substances to be heated can be inserted in the furnace via the open end. The ends of the element 2 may, of course, be closed by caps (not shown) or other means during operation, to reduce heat loss.

In operation, current flows from the control circuit 3 via the conductors 31 and 32 to the layer 20. With a lanthanum chromite layer, at room temperature, the resistance is high thereby resulting in an initial voltage across the element 2 of about 200 volts. Because of its negative temperature coefficient of resistance, the voltage drops rapidly to about 30 or 40 volts as the layer 20 heats up. The element 2 can be heated to about 1700°C; above about 500°C the resistance of the layer 20 is relatively constant enabling the temperature to be controlled readily. The increased thickness of the layer 20 in the regions 21 and 22 reduces its resistance, thereby reducing the heating effect in those regions and preventing damage to the silvered coatings 23 and 24.

The furnace element 2 is manufactured by applying the layer 20 to the tube 4 using a plasma-spraying technique. To form a layer of calcium-doped lanthanum chromite, a mixture is first made of lanthanum oxide, chromium oxide and calcium fluoride. This mixture is heated to between 1200°C and 1400°C and the resulting agglomerated, reacted mixture is then ground down to a fine powder. The powder is used in a standard plasma-spraying technique, that is, by spraying it on to the tube 4 through an electric arc which melts the particles of the powder. The increased thickness of the layer 20 at the end regions 21 and 22 is produced by spraying for a greater time.

Prior to spraying with the lanthanum chromite substance, a thin coating of chromium oxide may be applied to the surface of the tube 4 to improve the keying of the lanthanum chromite. The chromium oxide also helps replace any chromium that may be evaporated from the coating during use.

Because the layer 20 is on the outer surface of the tube 4 there is no danger of damaging electrically-sensitive articles placed within the element 2. The continuous nature of the layer 20 ensures that an even temperature is produced within the element, the good thermal contact produced by a coating leading to a rapid heating of the interior of the element. Since the exposed surface area of the layer 20 is relatively small, the amount of heat that is wasted on the outside of the element 2 is less than with some other forms of furnace. The use of a coating in the manner described above leads to a compact configuration of light weight and can be produced inexpensively. The need for operating the furnace element in an inert atmosphere is obviated by making the layer 20 of an oxide.

Furnaces in accordance with the present invention may be used in many different applications, such as, for the heat treating and doping of integrated electrical circuits, and for general laboratory and industrial use.

It wil be appreciated that various different materials could be used. For example, whilst alumina is suitable for the tube 4 at temperatures up to about 1700°C, other materials, such as, zirconia, hafnia or yttria could be used for higher temperatures. Various other conductive ceramics could be used to produce the layer 20, such as, for example, copper oxide (at low temperatures only), various alkaline earth-doped rare-earth chromites and manganites or silicon carbide.

The furnace element 2 could be of many different shapes and sizes, and the coating 20 could be arranged to produce a varying temperature along the length of the element such as, by making the coating of varying thickness or by varying the doping along its length.

The tube could be coated by other methods, such as, by painting or isostatic pressing.

Claims

1. A furnace element comprising a tubular member of an electrically-insulative ceramic material, wherein said tubular member is coated on its outer surface along a part at least of its length with an electrically-conductive ceramic material, such that, by passing current through the conductive ceramic material the interior of the tubular member can be heated.

2. A furnace element according to Claim 1, wherein said electrically-conductive ceramic material is an oxide.

3. A furnace element according to Claim 2, wherein said electrically-conductive ceramic material includes lanthanum chromite doped with calcium.

4. A furnace element according to any one of

the preceding claims, wherein said coating of electrically-conductive ceramic material is applied around the entire circumference of said tubular member along a part at least of its length.

5. A furnace element according to any one of the preceding claims, wherein one or both end portions of said tubular member are uncoated by said electrically-conductive ceramic material.

6. A furnace element according to any one of the preceding claims, wherein said coating of electrically conductive ceramic material is between substantially 4 mm and 6 mm thick.

7. A furnace element according to any one of the preceding claims, wherein said coating of electrically-conductive ceramic material varies in thickness along the length of the furnace element.

8. A furnace element according to Claim 7, wherein said coating of electrically-conductive ceramic material is thicker at the ends of the coating, and wherein electrical contact of the coating is made at these ends.

9. A furnace element according to Claim 1, wherein the ends of the electrically-conductive ceramic coating have metal layer thereon.

10. A furnace element according to Claim 9, wherein electrical contact of said metal layers is made by a flexible braided metal member.

11. A furnace element according to any one of the preceding claims, wherein said tubular member is of alumina.

12. A furnace element substantially as hereinbefore described with reference to the accompanying drawings.

13. A method of manufacture of a furnace element comprising the steps of providing a tubular member of an electrically-insulative ceramic material and forming on the outer surface of said tubular member along a part at least of its length a coating of electrically-conductive ceramic material.

14. A method according to Claim 13, wherein said coating of electrically-conductive ceramic material is applied by plasma spraying.

15. A method according to Claim 13 or 14, wherein said coating is of lanthanum chromite doped with calcium, and wherein a thin coating of chromium oxide is applied to said tubular member prior to said coating of lanthanum chromite.

16. A method of manufacture of a furnace element substantially as hereinbefore described with reference to the accompanying drawings.

17. A furnace element made by a method according to any one of Claims 13 to 16.

18. A furnace including a furnace element according to any one of Claims 1 to 12 or 17.

19. A furnace including a furnace element having a tubular member of an electrically-insulative ceramic material, and electrical means for heating said tubular member, wherein the tubular member is coated on its outer surface along a part at least of its length with an electrically-conductive ceramic material, and wherein the electrical means is connected with the coating and is arranged to supply current therethrough.

20. A furnace according to Claim 19, wherein said electrical means is arranged to control the voltage across the coating in response to change in temperature of the furnace, such as to tend to maintain said temperature substantially constant.

21. A furnace substantially as hereinbefore described with reference to the accompanying drawings.

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